Use of a high performance Lithium iron phosphate battery in the fuel cell range extender vehicle concept

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Abstract

A range extender vehicle concept is analyzed, in which the power train is driven mainly by a lithium iron phosphate (Li-$FePO_4$) battery. An on board fuel cell serves as an additional source of energy, which charges the high performance battery up to a certain SoC and therefore extends the range. Nowadays, the design of such a vehicle concept is trend of technology therefore a simulation tool plays a very important role for the prediction of the design. To get more accurate simulation results, a thermal modeling the of the li-ion battery is required.

Background

The existing simple map based battery model describes the electric behavior (internal resistance and open circuit voltage OCV) of the battery:

- *Internal resistance (charging and discharging): R = f (SoC) and OCV= f (SoC)*

In the new battery model, the change of the internal resistance due to temperature change of the battery will be accounted for a more accurate prediction of the available battery capacity:

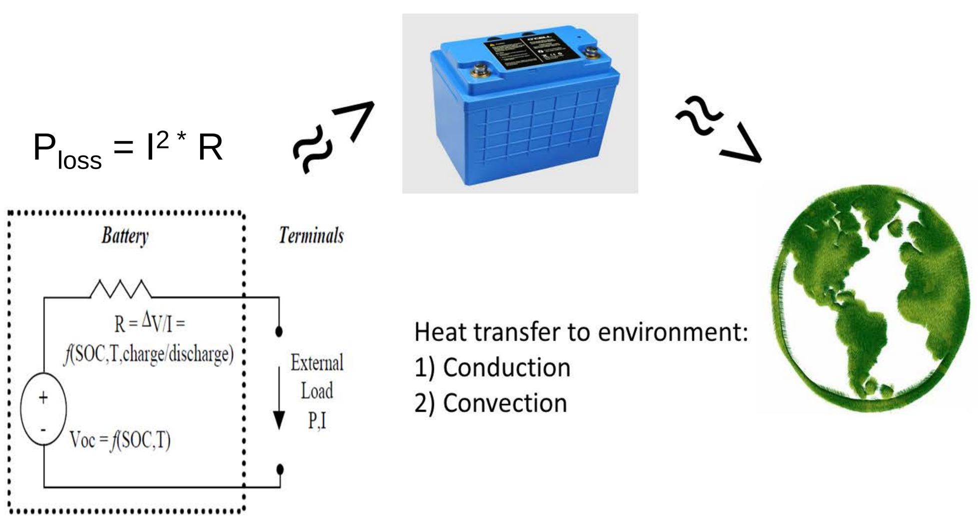
- *Internal resistance (charging and discharging) : R = f (SoC, temperature), OCV = f (SoC, temperature)*

Battery Test Specimen Details

Taken from manufacturer data sheet

Battery Type	Li-$FePO_4$
Manufacturer	BSOL Batteriesysteme GmbH
Nominal voltage, cut-off voltage	12 V, 10 V
Nominal Capacity	110 Ah
Height – Length – Width	224 – 260 – 158 mm
Mass	15 kg
Operating temperature	-20 – 60 °C

Thermal Modeling



Heat flow transfer to environment equation:

- Heat flow conduction = G*dT , where G = k*A/L
- Heat flow convection = Gc *dT, where Gc = A1*h
- Heat capacity = cp*m

Required parameters :

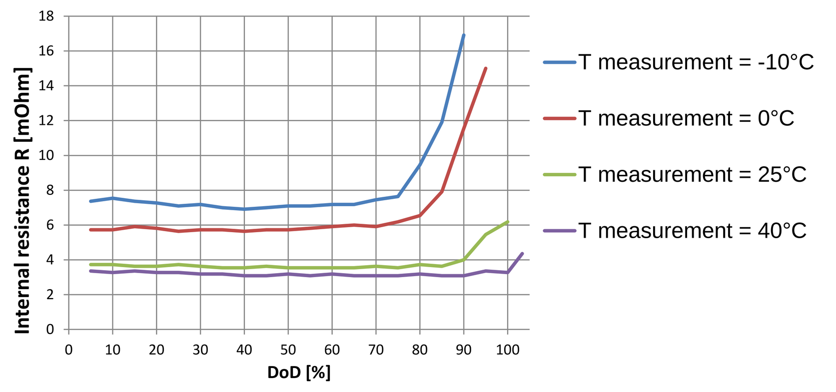
Thermal conductivity (k), Heat transfer coefficient (h) and Specific heat capacity (Cp)	Estimated from the literature review: [Muratori] [ChenSMIEEE] [ImkeKrüger] [Derek Brown] [Hossein Maleki], the thermal radiation is untended
Mass of battery (m), Conduction area of the battery box (A), Thickness of the battery box (L) and Convection area (A1)	Measured and calculated according to the boundary condition of the battery.

Experimental

Measurement of the internal resistance according to [VDA-initiative energy storage system for HEV] (charging and discharging) and open circuit voltage of li-ion battery depending on the temperature:

- Measurement temperatures at -10, 0, 25 and 40 °C
- Soaking of the battery for at least 2 hours till required measurement temperatures are reached
- Adequate pause between measurements to compensate the temperature changes in the battery

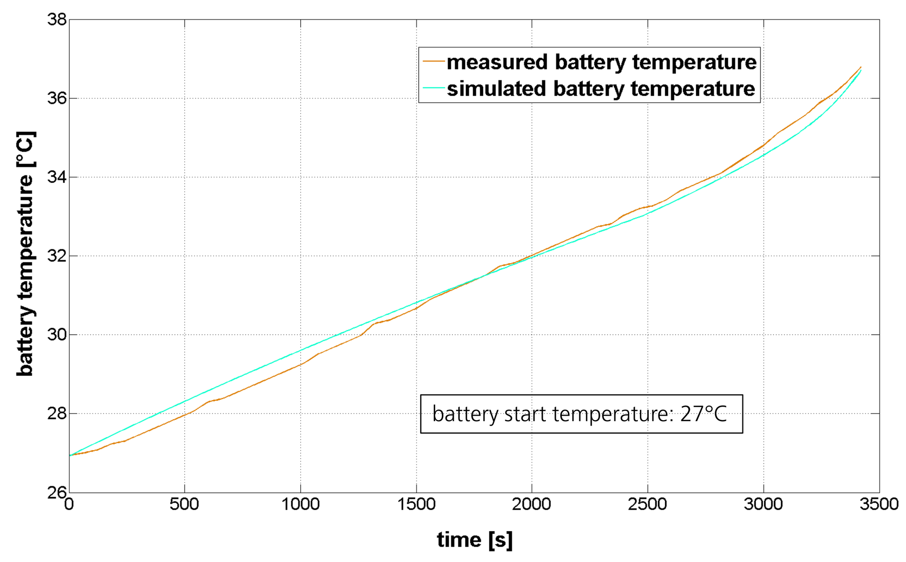
Figure of the test bench and experiment result



Measurements show a significant capacity loss at low temperature - The internal resistance increased rapidly at low SoC

Validation of the Map Based Thermal Battery Model

Validation of the battery model by comparing the measured and simulated battery temperature with 1 C discharge rate (110 A) without cooling (free convection) at room temperature (23 ± 0.5 °C)

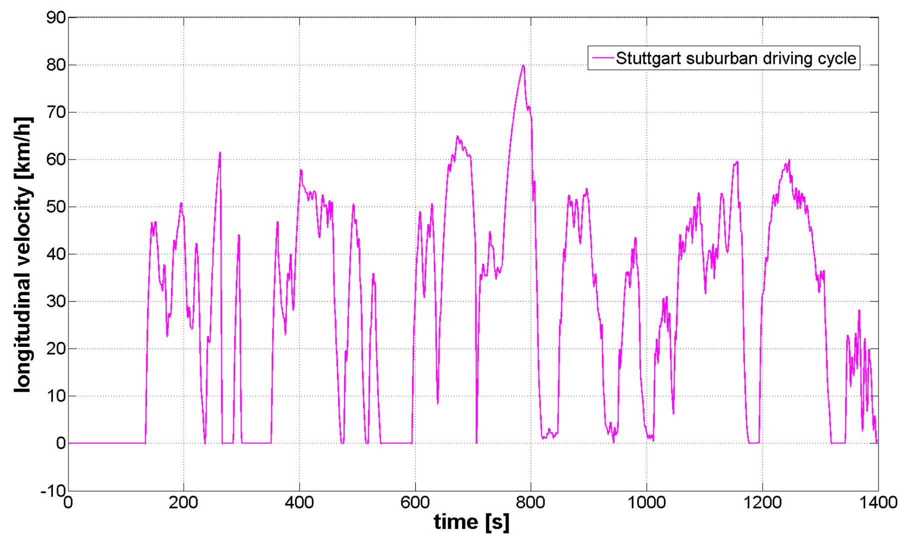


Simulation – Vehicle Concept

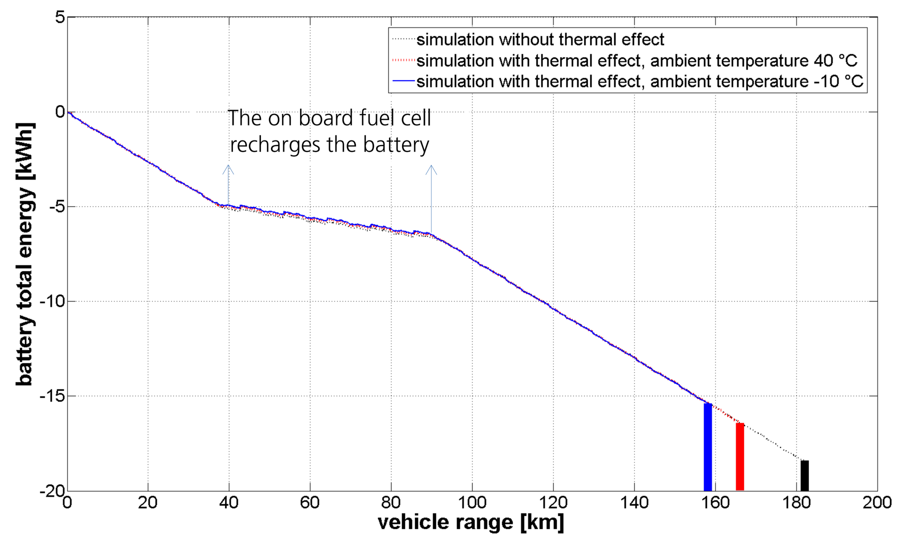
	Base vehicle: **Hylite - DLR fuel cell vehicle**
Vehicle class	City car
Vehicle tara weight (with Li-ion-batteries); Vehicle total weight (with driver, instrumentation & fuel cell)	702 kg; 1082 kg
Total battery mass and capacity	210 kg,18.48 kWh
Fuel cell system mass (with tank), continuous output; tank capacity	50 kg, 3.2 kW; 480 g (200 bar)
Motor performance and top speed	12 kW, 105 km/h

Simulation – Results

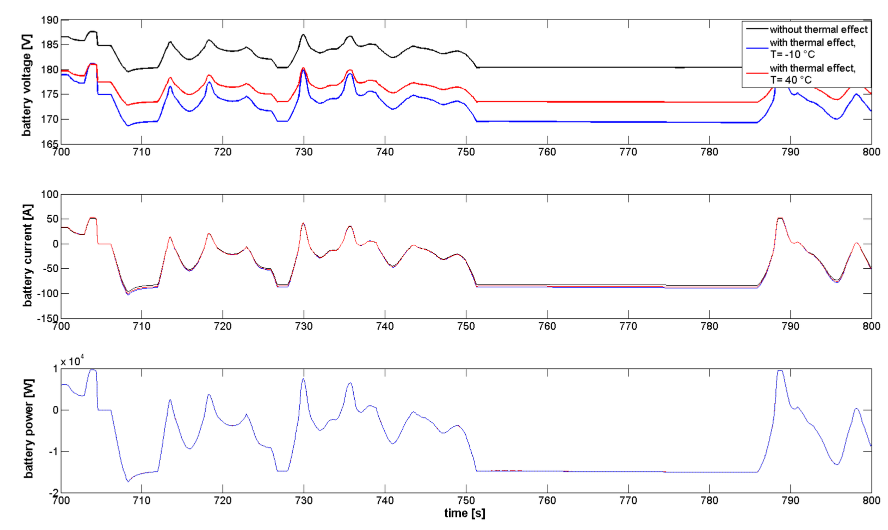
Simulation with real driving cycle: Stuttgart suburban (developed by DLR-Stuttgart) through: Vaihingen – Möhringen – Degerloch and Sillenbuch



- Battery electrical behavior:

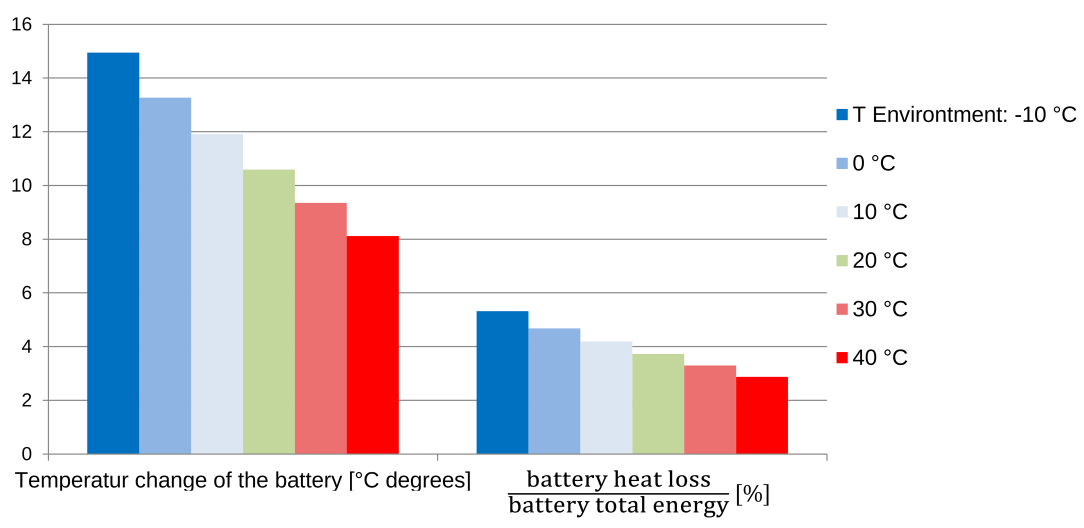


Lower available battery capacity due to the heat loss effect lower range of the vehicle



Lower open circuit voltage on the lower temperatur cause more current have been drawn from the battery on the same demand of load

- Battery thermal behavior



Higher heat loss at lower temperature due to higher internal resistance causes higher temperature change on the battery

Conclusion and Future Work

- The existing battery model was supplemented with the thermal dependence
- Comparison of measurement and simulation shows (at 1C) a good agreement
- The fuel cell range extender vehicle models has been upgraded with the new battery model and simulated
- The thermal dependence leads to the reduction of usable capacity and thus extends the range loss
- The validation of the whole vehicle simulation will be undertaken

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